

## Introduction to Main Injector Training

This document is your copy of our Main Injector Training. Its purpose is to assure that you receive the basic training necessary to develop safe and effective job skills required of an accelerator Operator 2. Further, it provides you with a listing of all of the information that is necessary to pass the Main Injector portion of the Operator 2 exam. It serves as checklist, guideline, and record of your training process. As such, **it is very important that you don't lose this**, or you may have to start over!

Here's how the process works:

Each numbered training topic has a description of what is to be accomplished, and a sign-off box to show that you have completed the training. The sign-off box identifies the person who assures that the training you receive is correct and complete. Many sign-off boxes identify this person simply as 'Trainer'. Your mentors most usually will serve the role of 'Trainer', although any Operator II or more senior member of this Operations Department may assume this task.

Trainer      Date

Here's an example of the format:

**##. Training Topic**

Description of what is to be accomplished.



Trainers initials and date of completion entered here.

The Main Injector Training Book is broken down into two sections:

**I. MCR On the Job Training:**

The primary purpose of the Main Injector **MCR OJT** is to introduce you to the procedures and tasks carried out on a day-to-day basis related to the Main Injector. Examples of **MCR OJT** include operation of MI power supplies, LCW systems, and tuning applications. The information covered in the **MCR OJT** will help the Operator 1 to develop the Main Injector control room skills that they will need to become a contributing Operator 2.

**II. Walkaround On the Job Training:**

The primary purpose of the Main Injector **Walkaround OJT** is to introduce you to the devices and locations outside the MCR that are important to the day to day operations of the Main Injector. Examples of **Walkaround OJT** include location of power supplies, RF equipment and systems necessary of MI operations. The information covered in the **Walkaround OJT** will help the Operator 1 develop the Main Injector skills needed to become a contributing Operator 2.

**III. Self Tests:**

The primary purpose of the Main Injector **Self-Tests** are to provide you with feedback on your progress in the training program. They are a set of self-paced tests composed of multiple choice, true/false, fill in the blank, and matching questions. There are three levels of self-tests. Level 1 is intended for the 3 to 6 month level, level 2 is intended for the 6 to 12 month level and level 3 is intended for the pre-op2 level. You can find the self tests at: <http://www-bd.fnal.gov/operations/selftest/selftest.html>.

Included at the back of this document are a few blank pages. These are for you to write in any comments about the training topics and process if you wish. Good luck on your new job, there is much for you to accomplish as you make your way to becoming an Operator II. You should find those who work with you to be helpful and friendly, just ask for assistance when you need it.

Best Wishes,

Fermilab Operations Department  
Training Committee

# Main Injector Training List Review

## Part 1: MCR OJT

### 8.1 Main Injector Introduction

1. MI Lattice
2. MI Tunnel Layout

### 8.2 Main Injector Safety

1. ESS/CDC inputs
2. Critical Devices
3. Power Supply Safety
4. Radiation Safety
5. Miscellaneous Hazards

### 8.3 Main Injector Power Supplies

1. Bend Bus Supplies
2. Quad Bus Supplies
3. Sextupole Power Supplies
4. Correction Elements

### 8.4 Main Injector RF

1. Modulators
2. Bias Supplies
3. Anode Supplies
4. RF Cavities
5. LLRF
6. Watchdogs

### 8.5 Main Injector Abort System

1. Abort Kickers
2. Abort Lambertsons
3. Abort Line Tuning
4. Monitoring the Abort

### 8.6 Main Injector MI-8 Line

1. Beamline Power Supplies
2. Permanent Magnets
3. Injection Lambertson
5. Injection Kickers
6. Beamline Tuning

### 8.7 Main Injector P1/P2/A1 lines

1. Power Supplies
2. Kickers
3. Lambertsons

### 8.8 Main Injector LCW Systems

1. MI Magnet Cooling
2. MIRF Cavity Cooling
3. MIRF RF Gallery

### 8.9 Main Injector Controls System

1. VME
2. CAMAC
3. PLC

### 8.10 Main Injector Instrumentation

1. BPMs
2. BLMs
3. SWICs
4. Toroids

### 8.11 Main Injector Tuning

1. Injection Tuning
2. Orbit Smoothing
3. Tunes & Chromaticity
4. 3-Bump Tuning
5. RPOS
6. LLRF
7. RF

## Part 2: Walkarounds

1. MI-60 Service Building
2. MI-40 Service Building
3. MI-52 Service Building

This training list has been successfully completed.

Department Head (Signature/Date) \_\_\_\_\_

**Operator**  
**Fermilab Accelerator Division Operations Department**

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Notes:

# Main Injector Training

## Part 1: MCR OJT

### 8.1 Main Injector Intro

Trainer      Date

#### 1. MI Lattice

- \_\_\_\_\_ Know what type of lattice the Main Injector has
- \_\_\_\_\_ Understand the following aspects of the Main Injector lattice:
  - \_\_\_\_\_ Know where the high dispersion regions are located
  - \_\_\_\_\_ Know where the low dispersion regions are located

Trainer      Date

#### 2. MI Tunnel Layout

- \_\_\_\_\_ Understand the numbering convention
  - \_\_\_\_\_ Know which locations have focusing or defocusing quads
- \_\_\_\_\_ Know where access points enter the tunnel
- \_\_\_\_\_ Know where the injection and extraction Lambertsons are for the following:
  - \_\_\_\_\_ MI-8 injection
  - \_\_\_\_\_ P1 line extraction
  - \_\_\_\_\_ A1 line extraction
  - \_\_\_\_\_ Transfer antiprotons to Recycler
  - \_\_\_\_\_ Transfer antiprotons from Recycler
  - \_\_\_\_\_ NUMI extraction
  - \_\_\_\_\_ Abort line extraction
- \_\_\_\_\_ Know where the RF cavities are located

### 8.2 Main Injector Safety

Trainer      Date

#### 1. ESS/CDC Inputs

- \_\_\_\_\_ Know what devices input to the MI ESS
- \_\_\_\_\_ Know what devices are interlocked to the MI ESS

- \_\_\_\_\_ Know what devices input to the Booster CDC (B:CRDEV) 8 GeV beam to MI mode
- \_\_\_\_\_ Know what devices are interlocked to the Booster CDC (B:CRDEV) 8 GeV beam to MI mode

## **2. Critical Devices**

Trainer	Date
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- \_\_\_\_\_ Identify the critical devices protecting the Main Injector tunnel and MI-8 line when B:CRDEV is in 8 GeV beam to MI mode
- \_\_\_\_\_ Identify the critical devices protecting the Main Injector tunnel and MI-8 line when B:CRDEV is in 8 GeV dump mode
- \_\_\_\_\_ Identify the critical devices protecting F sector

## **3. Power Supply Safety**

Trainer	Date
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- \_\_\_\_\_ Understand how the power supplies are interlocked to the safety system
- \_\_\_\_\_ Know which power supplies are Locked Out with the house safety disconnects
- \_\_\_\_\_ Know how to turn off or on before and after an access

## **4. Radiation Safety**

Trainer	Date
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- \_\_\_\_\_ Be familiar with the areas of the Main Injector tunnel that may be hotter than normal
- \_\_\_\_\_ Understand the radiation hazards associated with the RF cavities
- \_\_\_\_\_ Understand the areas that share a radiation safety system

## **5. Miscellaneous Safety**

Trainer	Date
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- \_\_\_\_\_ Understand the access procedure for the emergency exit mini-loops
- \_\_\_\_\_ Know how to search and secure the emergency exit mini-loops
- \_\_\_\_\_ Learn the locations and layouts of the MI/TeV no-mans-land crossovers

## 8.3 Main Injector Power Supplies

Trainer      Date

### 1. Bend Bus Power Supplies

- \_\_\_\_\_ Know where the upper and lower bus power supplies are located in each service building
- \_\_\_\_\_ Be able to take a power supply out of the circuit
- \_\_\_\_\_ Be able to put a power supply into the circuit
- \_\_\_\_\_ Know where to find the following power supply equipment
  - \_\_\_\_\_ Loop control hardware
  - \_\_\_\_\_ Hipot controller

Trainer      Date

### 2. Power Supply Control and Regulation

- \_\_\_\_\_ Know where the MECAR hardware is located
- \_\_\_\_\_ Be able to turn on the Main Injector ramp
- \_\_\_\_\_ Be able to halt the Main Injector ramp
- \_\_\_\_\_ Understand and be able to modify the PS turn-on order

Trainer      Date

### 3. Quad Bus Power Supplies

- \_\_\_\_\_ Know where the quad focusing power supplies are located
- \_\_\_\_\_ Know where the quad defocusing power supplies are located
- \_\_\_\_\_ Be able to take a power supply out of the circuit
- \_\_\_\_\_ Be able to put a power supply into the circuit

Trainer      Date

### 4. Sextupole Power Supplies

- \_\_\_\_\_ Know where the sextupole power supplies are located
- \_\_\_\_\_ Understand the impact of an F Sector access on the Sextupole power supplies

Trainer      Date

## 5. Correction Element Power Supplies

- \_\_\_\_\_ Know where the correction element power supplies are located
- \_\_\_\_\_ Be able to enable/disable C.E. ramps
- \_\_\_\_\_ Be able to save/restore C.E. ramps before tuning or after a power outage

# 8.4 Main Injector RF

Trainee      Date

## 1. Modulators

- \_\_\_\_\_ Locate the MI RF modulators
- \_\_\_\_\_ Be able to turn on and off a modulator, including completely shutting down the modulator
- \_\_\_\_\_ Understand the purpose of the modulators

Trainee      Date

## 2. Bias Supplies

- \_\_\_\_\_ Locate the MI RF bias supplies
- \_\_\_\_\_ Understand the function of the bias supply

Trainee      Date

## 3. Anode Supplies

- \_\_\_\_\_ Know where the anode supplies are located
- \_\_\_\_\_ Know where the local controls for the anode supplies are located
- \_\_\_\_\_ Understand the purpose of the anode power supplies

Trainee      Date

## 4. RF Cavities

- \_\_\_\_\_ Know where the RF cavities are located
- \_\_\_\_\_ Know where the coalescing cavities are located
- \_\_\_\_\_ Understand the basic differences between Booster, Main Injector, and Tevatron RF cavities
- \_\_\_\_\_ Understand how the RF cavities are cooled



- \_\_\_\_\_ Draw a block diagram of the RF system including a Modulator, Bias supply, Anode supply and an RF cavity

**5. LLRF**

Trainer	Date
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- \_\_\_\_\_ Know where the MI LLRF system is located
- \_\_\_\_\_ Know how to reboot the MI LLRF system
- \_\_\_\_\_ Know the operating RF frequency range for the MIRF
- \_\_\_\_\_ Know how to tune these LLRF parameters for any event
- \_\_\_\_\_ Injection phase offset
- \_\_\_\_\_ Acceleration phase
- \_\_\_\_\_ Transition timing
- \_\_\_\_\_ Transition phase jump

**6. RF Watchdogs**

Trainee	Date
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- \_\_\_\_\_ Find out what the RF watchdog system monitors
- \_\_\_\_\_ Be able to respond appropriately to an RF watchdog alarm

## **8.5 Main Injector Abort System**

**1. Abort Kickers**

Trainer	Date
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- \_\_\_\_\_ Be able to verify and set the abort clean-up times for any cycle
- \_\_\_\_\_ Understand the two different ways the abort kickers can be triggered
- \_\_\_\_\_ Know the location of the abort kickers
- \_\_\_\_\_ Understand which plane the kickers kick the beam on and how to tune the kickers to minimize beam loss

**2. Abort Lambertson**

Trainer	Date
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- \_\_\_\_\_ Know on which plane the Lambertson will effect the beam
- \_\_\_\_\_ Be able to tune the Lambertson to minimize losses
- \_\_\_\_\_ Understand the importance of the circulating beam position through the Lambertson and how to tune it

Trainer      Date

### 3. Abort Line Tuning

- \_\_\_\_\_ Be able to tune the kickers, Lambertsons and dipole trims in the abort line to minimize beam loss

Trainer      Date

### 4. Monitoring the Abort

- \_\_\_\_\_ Be able to jumper and unjumper inputs to the abort link
- \_\_\_\_\_ Understand who is authorized to jumper abort inputs
- \_\_\_\_\_ Know which loss monitors are used to monitor abort line losses
- \_\_\_\_\_ Plot the abort SWIC and identify if the beam is positioned properly
- \_\_\_\_\_ Check the abort efficiency using the abort line toroid

Trainer      Date

### 5. Understand the role the C204 and C200 links play in the Main Injector Abort systems

- Be aware of the MI abort link
- \_\_\_\_\_ Understand the layout and basic make-up of the MI & MI related transfer lines C200 abort link
- \_\_\_\_\_ Understand the make-up and relationship of the MI & MI related transfer lines C204 system to the C200 system
- \_\_\_\_\_ Be aware of the hardwired abort reset button located in the MCR

## 8.6 Main Injector MI-8 Line

Trainer      Date

### 1. Beamline Power Supplies

- \_\_\_\_\_ Know the location of the upstream and downstream power supplies
- \_\_\_\_\_ Know where the CAMAC crates are that control the MI-8 line power supplies

Trainee      Date

### 2. Permanent Magnets

- \_\_\_\_\_ Know where the permanent magnets start in the MI-8 line, and how far down the line they go
- \_\_\_\_\_ Understand the MI-8 line electrical safety system with respect to the permanent magnets

Trainer      Date

**3. Injection Lambertson**

\_\_\_\_\_ Be able to properly tune the Lambertson to reduce beam losses

Trainer      Date

**4. Injection Kickers**

\_\_\_\_\_ Be able to properly tune the kickers to reduce beam losses

Trainer      Date

**5. Beamline Tuning**

- \_\_\_\_\_ Be able to tune the MI-8 line using the auto-tune programs
- \_\_\_\_\_ Understand the impact of changing beam line positions upstream of the kickers or Lambertson
- \_\_\_\_\_ Be able to perform the sequence of beam line tuning, orbit smoothing, and injection closing as described in the MI Tuning UTES book

## 8.7 Main Injector P1/P2/A1 Beam lines

Trainer      Date

**1. Power Supplies**

- \_\_\_\_\_ Know where the power supplies are located for the P1/P2/A1 beam lines
- \_\_\_\_\_ Understand how the beam line power supplies are tuned using I68
- \_\_\_\_\_ Understand the idea of the load switch and how to verify if the switch is functioning

Trainer      Date

**2. Kickers**

- \_\_\_\_\_ Know which kickers kick the beam down each of the beam lines
- \_\_\_\_\_ Understand the kicker triggers
- \_\_\_\_\_ Know where the kicker power supplies are located
- \_\_\_\_\_ Know how to check and tune the positions at extraction

### 3. Lambertsons

Trainer	Date
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- \_\_\_\_\_ Know how to properly tune the Lambertson
- \_\_\_\_\_ Be able to check and tune the positions at the lambertsons
- \_\_\_\_\_ Know where the Lambertson power supplies are located

## 8.8 Main Injector LCW Systems

### 1. MI Magnet Cooling

Trainer	Date
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- \_\_\_\_\_ Understand the flow path for the magnet cooling system
- \_\_\_\_\_ Understand where the Main Injector make up water comes from
- \_\_\_\_\_ Understand how the LCW system maintains head pressure and what to do if the pressure falls to low
- \_\_\_\_\_ Be able to monitor the LCW system including the following:
  - \_\_\_\_\_ Supply pressure
  - \_\_\_\_\_ Return pressure
  - \_\_\_\_\_ Temperature
  - \_\_\_\_\_ Leak alarms

### 2. MIRF Cavity Cooling

Trainer	Date
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- \_\_\_\_\_ Know where the cavity cooling system is located
- \_\_\_\_\_ Know where the cavity cooling system makes up water from
- \_\_\_\_\_ Know the general operating temperature and pressure ranges for the cavity LCW system

### 3. MIRF RF Gallery

Trainer	Date
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- \_\_\_\_\_ Know where the RF gallery system is located
- \_\_\_\_\_ Know how the RF gallery system makes up water
- \_\_\_\_\_ Know the general operating parameters for the RF gallery LCW system

## 8.9 Main Injector Controls Systems

Trainer	Date
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### 1. CAMAC

- \_\_\_\_\_ Understand the layout of the CAMAC link
- \_\_\_\_\_ Be able to trouble shoot basic CAMAC system failures
- \_\_\_\_\_ Understand which systems use CAMAC controls

Trainer	Date
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### 2. VME

- \_\_\_\_\_ Know which systems use VMEs or VXIs
- \_\_\_\_\_ Know where the various crates are located
- \_\_\_\_\_ Be able to diagnose simple VME or VXI failures

Trainer	Date
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### 3. PLC

- \_\_\_\_\_ Know which systems use PLCs
- \_\_\_\_\_ Know where the various PLCs are located
- \_\_\_\_\_ Be able to diagnose simple PLC failures

## 8.10 Main Injector Instrumentation

Trainer	Date
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### 1. BPMs

- \_\_\_\_\_ Understand how to acquire an injection flash orbit
- \_\_\_\_\_ Understand how to acquire a last turn flash orbit
- \_\_\_\_\_ Know how to take a display orbit at any energy breakpoint
- \_\_\_\_\_ Know how to take profile frames at each breakpoint
- \_\_\_\_\_ Be able to reboot and reload MI BPMs

Trainer	Date
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### 2. BLMs

- \_\_\_\_\_ Know how to plot individual BLMs
- \_\_\_\_\_ Know how to acquire ring wide loss displays

### 3. SWICs

Trainer	Date
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- \_\_\_\_\_ Know how to use the abort SWIC
- \_\_\_\_\_ Know how to use the P1/P2 line SWICs

### 4. Toroids

Trainer	Date
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- \_\_\_\_\_ Know where all of the toroids associated with MI beam are located and how to monitor them

## 8.11 Main Injector Tuning

### 1. Injection Tuning

Trainer	Date
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- \_\_\_\_\_ Know the individual steps and correct order:
  - \_\_\_\_\_ to establish correct momentum
  - \_\_\_\_\_ to smooth
  - \_\_\_\_\_ to match Booster momentum
  - \_\_\_\_\_ to perform closure

### 2. Orbit Smoothing

Trainer	Date
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- \_\_\_\_\_ Know what needs to be done before smoothing the orbit
- \_\_\_\_\_ Know how to smooth the orbit at injection and up the ramp
- \_\_\_\_\_ Know how to recover and back out of a smooth

### 3. Tunes and Chromaticities

Trainer	Date
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- \_\_\_\_\_ Be able to measure the tunes at injection
- \_\_\_\_\_ Be able to correctly tune the tunes using I2
- \_\_\_\_\_ Be able to correctly tune the chromaticity using I2

Trainer      Date

#### **4. 3-Bump Tuning**

- \_\_\_\_\_ Know how to correctly set up a 3-bump at various breakpoints
- \_\_\_\_\_ Be able to tune out losses with a 3-bump

Trainer      Date

#### **5. RPOS**

- \_\_\_\_\_ Know how to center the beam after feedback on-time

Trainer      Date

#### **6. LLRF**

- \_\_\_\_\_ Know how to tune the injection phase offset
- \_\_\_\_\_ Know how to tune the acceleration phase offset
- \_\_\_\_\_ Know how to tune transition timing and phase jump

Trainer      Date

#### **7. RF**

- \_\_\_\_\_ Understand the proper way to tune the RF high voltage curves via I3

**Operator**  
**Fermilab Accelerator Division Operations Department**

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Notes:



# Main Injector Training

## Part 2: Walkaround OJT

### 1 MI-60 Service Building

Trainer	Date
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- \_\_\_\_\_ Locate the MI-60 upper bend PS
- \_\_\_\_\_ Locate the MI-60 lower bend PS
- \_\_\_\_\_ Locate the MI-60 quad focusing PS
- \_\_\_\_\_ Locate the control hardware for the MI bend and quad power supply loops
- \_\_\_\_\_ Find the RF modulators and bias supplies
- \_\_\_\_\_ Locate all three MI anode supplies
- \_\_\_\_\_ Locate the MI-60 LCW room
- \_\_\_\_\_ Find and be able to change the MI-60 nitrogen bottle that provides LCW pressure

### 2 MI-40 Service Building

Trainer	Date
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- \_\_\_\_\_ Locate the abort kicker power supplies
- \_\_\_\_\_ Locate the abort Lambertson power supplies
- \_\_\_\_\_ Locate the bend power supplies
- \_\_\_\_\_ Locate the quad power supply and identify which quad bus this powers
- \_\_\_\_\_ Locate the CAMAC crates associated with MI-40
- \_\_\_\_\_ Locate the VME crate
- \_\_\_\_\_ Locate the correction element power supplies and regulators
- \_\_\_\_\_ Locate the abort patch panel
- \_\_\_\_\_ Locate the LCW system and the associated PLC
- \_\_\_\_\_ Locate the VESDA display panel for local readouts

### 3 MI-52 Service Building

Trainer	Date
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- \_\_\_\_\_ Locate the P1 line extraction Lambertson power supply
- \_\_\_\_\_ Locate the P1 line extraction kicker power supplies
- \_\_\_\_\_ Locate the horizontal and vertical sextupole power supplies